



**TECHNICAL REPORT
NATICK/TR-00/014**

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**FIELD EVALUATION OF THE SIZING AND TARIFF
OF THE U.S. MARINE CORPS INTERCEPTOR BODY ARMOR**

by
J. David Brantley

July 2000

Final Report
March 1999 - November 1999

Approved for Public Release; Distribution is Unlimited

**U.S. Army Soldier and Biological Chemical Command
Soldier Systems Center
Natick, Massachusetts 01760-5050**

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|---|-------------------------|--------------------------|--|---|---|
| 1. REPORT DATE (DD-MM-YYYY) 7-7-00 | | 2. REPORT TYPE FINAL | | 3. DATES COVERED (From - To) March 1999 - November 1999 | |
| 4. TITLE AND SUBTITLE FIELD EVALUATION OF THE SIZING AND TARIFF OF THE U.S. MARINE CORPS INTERCEPTOR BODY ARMOR | | | | 5a. CONTRACT NUMBER JON; 9BV412 JON; 9CN12P | |
| | | | | 5b. GRANT NUMBER | |
| | | | | 5c. PROGRAM ELEMENT NUMBER | |
| | | | | 5d. PROJECT NUMBER | |
| 6. AUTHOR(S) J. David Brantley | | | | 5e. TASK NUMBER | |
| | | | | 5f. WORK UNIT NUMBER | |
| | | | | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Soldier and Biological Chemical Command Natick Soldier Center ATTN: AMSSB-RSS-E (N) (J. David Brantley) Natick, MA 01760-5050 | | | | 8. PERFORMING ORGANIZATION REPORT NUMBER NATICK/TR-00/014 | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) <i>Meaningful Color Pages</i> | | | | 10. SPONSOR/MONITOR'S ACRONYM(S) | |
| | | | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for Public Release; Distribution Unlimited | | | | | |
| 13. SUPPLEMENTARY NOTES | | | | | |
| 14. ABSTRACT This study was conducted to determine the most accurate initial tariff for the United States Marine Corps Interceptor Body Armor. The approach included determining the actual tariff of the units involved by issuing the Interceptor to individual Marines based on their chest circumference measurements, as well as a fit test and user survey to assess the sizing, design and fit of all sizes of the Interceptor. The unit tariff was compared to the anthropometric tariff based on the 1995 USMC database and a revised tariff was calculated for the Interceptor. The fit test and survey results were used to determine any design and sizing changes needed to improve the fit of the Interceptor. The predicted size was rated acceptable by 84.7% of the participants and was also the best fitting size for 70.4% of the Marines evaluated. The main reasons for someone's predicted size to be rated unacceptable were: 1. the chest/waist circumference was too big and 2. the vest was too long. Once the recommended design changes have been applied, further increases in acceptability can only be achieved by creating additional sizes for the Interceptor based on length in addition to chest circumference. | | | | | |
| 15. SUBJECT TERMS ANTHROPOMETRY DESIGN CRITERIA PROPER FIT INTERCEPTOR BODY ARMOR FIELD EVALUATION FIT EVALUATION OVERVESTS BODY ARMOR TARIFF SIZES SIZING CRITERIA CHEST(ANATOMY) | | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT SAR | 18. NUMBER OF PAGES 45 | 19a. NAME OF RESPONSIBLE PERSON J. David Brantley |
| a. REPORT UNCLSFED | b. ABSTRACT UNCLSFED | c. THIS PAGE UNCLSFED | | | 19b. TELEPHONE NUMBER (Include area code) 508-233-4974 |

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PREFACE

In preparation for full production of the Interceptor and its delivery to U.S. Marine Corps units, this study was conducted to determine the most accurate initial tariff. The approach included determining the actual tariff of the units involved by issuing the vest to individual Marines based on their chest circumference measurements, as well as a fit test and user survey to assess the sizing, design, and fit of all sizes of the Interceptor. The unit tariff was compared to the anthropometric tariff based on the 1995 USMC database, and the fit test and survey results were used to determine what, if any, design and sizing changes might be needed to improve the fit of the Interceptor.

The Ergonomics Team, Supporting Science & Technology Directorate, Natick Soldier Center performed this study for the Marine Corps Customer Team, Individual Protection Directorate, Natick Soldier Center. The Marine Corps Systems Command and the U.S. Army PM-Soldier provided funding.

ACKNOWLEDGEMENTS

The enthusiastic participation and cooperation of the Marines from the 3rd Battalion, 2nd Marines at Camp Lejeune and the 1st Light Armored Recon Battalion at Camp Pendleton made this project possible. I would also like to thank everyone who assisted me as members of the measure, issue, and fit-test team: Rose Guerra, Ed Hennessy, and Brian Corner from the Ergonomics Team, NSC; Dee Townes, Major Gabriel Patricico, and Victor Palumbo from the Marine Corps Customer Team, NSC; Al Price and Rick Hockensmith from Point Blank Body Armor; Mary Hoffman from Battelle; and Rick Fiorey from the Defense Contract Management Center-Orlando. The follow-up survey was derived from a survey prepared by Chuck Greene from the Product Optimization and Evaluation Team, NSC and administered by Jon Laplume from the Marine Corps Customer Team, NSC.

Introduction

Determining an accurate tariff, the number of each size of an item needed to fit a group of people, for a newly developed item like the Interceptor body armor is an important part of containing the overall life cycle costs. An initial tariff is usually calculated by sorting an anthropometric database according to the sizing chart for the item. The accuracy of such a tariff will depend on two main factors. The first is the proper design and sizing of the item itself. The second is similarity of the real user population to the database population used to determine the tariff. Both are important as well as interdependent. An item designed to fit one group of people may or may not fit a different group in the same way.

A properly designed and sized item is one that adequately fits specified body measurements, or range of measurements. If a vest size Medium is meant to accommodate a range of chest circumference measurements from 37 inches to 41 inches, then most people within that range should fit in that vest. If, however, that vest actually accommodates some other range of measurements, any tariff based on the intended range of 37 inches to 41 inches will not be accurate. Such a vest could be redesigned to fit the intended range, or the size chart of the vest could be changed to reflect the actual accommodation range.

The user population must also be determined before an accurate tariff can be calculated. For military populations, the key information is whether an item will be used by both males and females, or only one or the other, and whether the item is intended for general use or for use by specific groups which may have unique body size requirements, like pilots. Once the intended user population is identified, the appropriate database can be used to determine the tariff.

In preparation for full production of the Interceptor and its delivery to U.S. Marine Corps units, this study was conducted to determine the most accurate initial tariff. The approach included determining the actual tariff of the units involved by issuing the vest to individual Marines based on their chest circumference measurements, as well as a fit test and user survey to assess the sizing, design, and fit of all sizes of the Interceptor. The unit tariff was compared to the anthropometric tariff based on the 1995 USMC database (Donelson & Gordon, 1996), and the fit test and survey results were used to determine what, if any design and sizing changes might be needed to improve the fit of the Interceptor. It was decided that if changes in the vest were needed, the original sizing would be maintained and the Interceptor patterns would be altered to better accommodate the intended range of chest circumference measurements.

Methods and Materials

The Interceptor

The Interceptor is a ballistic protective over vest, intended to replace the currently used vest (flak jacket or PASGT). It is made to be worn over the first few layers of clothing. It has removable front and back ceramic plates and modular attachments including a collar with padded yoke, a groin protector, and a throat protector. It has an overlapping front opening and overlapping adjustable sides. The vest has five sizes designed to accommodate at least 90% of both males and females in the Marine Corps (Table 1).

Table 1. Interceptor Sizing

| Size | Chest Circ. (inches) |
|--------|----------------------|
| | Male / Female |
| XSmall | Under 33 |
| Small | 33 – 37 / 33 – 38 |
| Medium | 37 – 41 / 38 – 42 |
| Large | 41 – 45 / Over 42 |
| XLarge | Over 45 / NA |

The vests used in this study were manufactured in April 1999 by Point Blank Body Armor, Inc., and included all modular attachments, but did not include ceramic plates (Point Blank Body Armor, Inc., 1999). All five sizes were used.

The Sample

Chest circumference was measured for Interceptor sizing and issuing on 1027 active duty male Marines, enlisted and officer. This included 454 Marines from 3rd Battalion, 2nd Marines at Camp Lejeune, NC and 573 Marines from 1st Light Armored Reconnaissance Battalion at Camp Pendleton, CA. From the total sample, 251 participated in fit evaluations, and 161 completed a follow up survey. No females participated in this study.

Sizing, Issuing, and Fit Evaluation

This study had two objectives. The first was to measure the chest circumference of all participating Marines in order to determine their predicted size and issue them the Interceptor. These measurements were used to determine the actual unit tariff. The second was to evaluate the fit of the Interceptor on selected Marines in each size. The original plan was to measure and issue first and then have selected Marines return for the fit evaluation. However, it turned out to be more efficient to do both parts simultaneously. Sizing, issuing, and fit evaluation were done at both Camp Lejeune and Camp Pendleton.

As Marines entered the test area they received data forms (Figure 1) and completed a personal information section that included unit, name, rank, MOS, time in service, age, date of birth, and race or ethnicity. Each Marine removed his shirt and an anthropologist measured chest circumference to the nearest millimeter using a tape measure on the surface of the skin (Clauser et al, 1988). A human factors specialist observed and assisted the measurement process and recorded the chest circumference value and the predicted size on the data form. Comments were recorded as needed. Each Marine then took his data form to a vest issuing point and received the predicted size Interceptor, and finally, returned the data form at a check out point where the measurement value, predicted size, and actual vest size were verified.

During this process, the measurement team randomly selected Marines to remain for the fit evaluation. The selection process was primarily based on traffic flow so that congestion in the area and wait times were minimized. Once sampling goals for particular sizes began to be met, selection was based on predicted size. In addition, any Marines who returned requesting a

different size were included in the fit evaluation. The initial goal was to evaluate all those whose predicted size was XSmall or XLarge, and 50 each whose predicted size was Small, Medium, or Large. For all Marines in the fit evaluation, an anthropologist measured stature, neck circumference base, waist circumference omphalion, and waist front length to the nearest millimeter using an anthropometer and tape measure (Clauser et al, 1988). Weight was measured to the nearest 1/10th kilogram using an electronic scale. Due to the large number of subjects and limited schedule, no landmarking was done for the measurements.

Once the measurements were recorded, each Marine tried on his predicted size and the next closest size. Two observers made qualitative assessments of each, with input from the Marine. At least one of the observers was a human factors specialist or an anthropologist. They evaluated the fit of chest and waist, length, arm openings, and neck opening on a three-point scale. The evaluation included having the Marine perform some basic movements such as reaching overhead with both arms, crossing both arms over the chest, bending at the waist, and kneeling on one knee. The observers then asked the Marine to rate the overall fit as acceptable or not acceptable. After rating both sizes, a best fitting vest was chosen and the Marine was issued that size.

| VEST ISSUING DATA FORM | |
|---|---------------------------------|
| Please Print in Ink | |
| 1. Unit _____ | Ba. _____ Co. _____ Other _____ |
| 2. Last Name _____ | |
| 3. First Name _____ | |
| 4. Rank (ex. E5 / Sergeant) _____ | |
| 5. MOS _____ | |
| 6. Time in Service _____ years _____ months | |
| 7. Age _____ | |
| 8. Date of Birth Day _____ Month _____ Year _____ | |
| 9. Gender: <input checked="" type="checkbox"/> Male(1) | |
| 10. Race / Ethnicity: <div style="display: flex; justify-content: space-between;"> ___ White, not Hispanic(1) ___ Black, not Hispanic(2) </div> <div style="display: flex; justify-content: space-between;"> ___ Asian / Pacific Islander(3) ___ Hispanic(4) </div> <div style="display: flex; justify-content: space-between;"> ___ American Indian / Native Alaskan(5) </div> | |
| STOP! Please do not write below this line. | |
| 11. Chest Circumference _____ mm | |
| <div style="display: flex; align-items: flex-start;"> <div style="flex: 1;"> 12. Vest Size Predicted <input type="checkbox"/> XSmall(1) 735 - 788 - 838 <input type="checkbox"/> Small(2) 839 - 859 - 939 <input type="checkbox"/> Medium(3) 940 - 990 - 1040 <input type="checkbox"/> Large(4) 1041 - 1091 - 1142 <input type="checkbox"/> XLarge(5) 1143 - 1193 - 1245 </div> <div style="flex: 0.5; border: 1px solid black; padding: 5px; margin-left: 10px; font-size: 0.8em;"> Circle appropriate half of range </div> </div> | |
| 13. Vest Issued <input type="checkbox"/> Yes(1)* <input type="checkbox"/> No(2) | |
| *Measurement value is within the range for the vest issued. | |
| Comments: _____ | |

| FIT TEST DATA FORM | |
|--|--|
| Please do not write on this form. | For evaluator use only. |
| 1. Stature _____ | 4. Neck Circ. _____ |
| 2. Weight _____ | 5. Waist Circ. Om. _____ |
| 3. Chest Circ. _____ (see issue data form) | 6. Waist Front _____ |
| 7. Issued Vest Size _____ (see issue data form) | 8. Nearest Adjacent Vest Size _____ (see issue data form) |
| A. Chest / Waist <input type="checkbox"/> Too Big(1) <input type="checkbox"/> OK(2) <input type="checkbox"/> Too Small(3) | A. Chest / Waist <input type="checkbox"/> Too Big(1) <input type="checkbox"/> OK(2) <input type="checkbox"/> Too Small(3) |
| B. Length <input type="checkbox"/> Too Short(1) <input type="checkbox"/> OK(2) <input type="checkbox"/> Too Long(3) | B. Length <input type="checkbox"/> Too Short(1) <input type="checkbox"/> OK(2) <input type="checkbox"/> Too Long(3) |
| C. Arm Openings <input type="checkbox"/> Too Small(1) <input type="checkbox"/> OK(2) <input type="checkbox"/> Too Big(3) | C. Arm Openings <input type="checkbox"/> Too Small(1) <input type="checkbox"/> OK(2) <input type="checkbox"/> Too Big(3) |
| D. Neck <input type="checkbox"/> Too Small(1) <input type="checkbox"/> OK(2) <input type="checkbox"/> Too Big(3) | D. Neck <input type="checkbox"/> Too Small(1) <input type="checkbox"/> OK(2) <input type="checkbox"/> Too Big(3) |
| E. Fit is: <input type="checkbox"/> Acceptable(1) <input type="checkbox"/> Not Acceptable(2) | E. Fit is: <input type="checkbox"/> Acceptable(1) <input type="checkbox"/> Not Acceptable(2) |
| 9. BEST FITTING SIZE: Evaluator _____ Marine _____ If issued size is not the best fitting size, re-issue vest.* | |
| 10. The best fitting vest size has been issued <input type="checkbox"/> Yes(1) <input type="checkbox"/> No(2)* | |
| *Comments: _____ | |

Figure 1. Sizing, issuing, and fit test data form, front and back.

The Follow up Survey

Twelve weeks after being issued the Interceptor, several groups of Marines from 1st Light Armored Reconnaissance Battalion at Camp Pendleton, CA completed a survey (Figure 2) to evaluate sizing and fit, general functionality, and how the Interceptor compared to the body armor previously used by the Marines (PASGT vest). Results of the survey and the previous fit evaluation were the basis for recommended design changes.

| Interceptor Body Armor Review Questionnaire | |
|--|--|
| <p>The U.S. Marine Corps is conducting an initial fielding evaluation of the Interceptor Body Armor system. By participating in this evaluation you will be providing valuable feedback to the Marine Corps. It is important that you take this questionnaire seriously. Answer each item as completely and honestly as you can. If anything is not clear, or if you have a question about the evaluation, please ask about it. Thank you for your time.</p> | |
| <p>1. Last Name: _____</p> <p>2. First Name: _____</p> <p>3. Battalion: _____</p> <p>4. Company: _____</p> | <div style="border: 1px solid black; width: 80px; height: 80px; margin: 0 auto; display: flex; align-items: center; justify-content: center;">5.</div> |
| <p>6. Are you using the same vest you were issued when your chest was measured? YES NO</p> | |
| <p>IF NO,</p> <p>7. Why did you change your vest? Please be specific. _____</p> | |
| <p>8. Did you change sizes? NO YES, changed to XS S M L XL</p> | |
| <p>9. Approximately how many days have you worn the Interceptor? _____ days</p> | |
| <p>10. Approximately how many hours per day did you usually wear it? _____ hours</p> | |
| <p>11. Were you able to adjust Interceptor so that it fit you properly? YES NO</p> | |
| <p>12. IF NO, please explain. _____</p> | |
| <p>13. Overall, were you satisfied with the way the Interceptor fit? YES NO</p> | |
| <p>14. IF NO, what problems did you have? Please be specific. _____</p> | |
| <p>15. Do you think a different size, smaller or larger, would fit you better? YES NO</p> | |
| <p>16. If YES, which size? XS S M L XL</p> | |
| <p>17. Did the Interceptor interfere with any clothing or equipment items? (cammys, Goretex, helmet, pack, radio, weapon, etc.) YES NO</p> | |
| <p>18. If YES, please describe the problem. _____</p> | |
| <p>19. - 26. Which is better for each of the following factors: the body armor you used before or the Interceptor? Circle one answer for each.</p> | |
| 19. Proper sizing and fit | PREVIOUS INTERCEPTOR |
| 20. Amount of body area covered | PREVIOUS INTERCEPTOR |
| 21. Level of protection offered | PREVIOUS INTERCEPTOR |
| 22. Ability to move when wearing it | PREVIOUS INTERCEPTOR |
| 23. Compatibility with clothing items | PREVIOUS INTERCEPTOR |
| 24. Compatibility with equipment items | PREVIOUS INTERCEPTOR |
| 25. Ability to perform your mission | PREVIOUS INTERCEPTOR |
| 26. Overall | PREVIOUS INTERCEPTOR |
| <p>27. Was the instruction that you received on the Interceptor adequate? YES NO</p> | |
| <p>28. IF NO, what do you need more information on? _____</p> | |
| <p>29. List any other comments or suggestions regarding the Interceptor Body Armor.</p> <p>_____</p> <p>_____</p> <p>_____</p> | |

Figure 2. Follow up survey, front and back.

Results

Actual Unit Tariff

Based on the predicted sizes for the 1027 Marines measured for chest circumference, a combined unit tariff was calculated. Only one Marine had a chest circumference outside the sizing range. However, the size XLarge provided an acceptable fit for this Marine. All others, 99.9%, were predicted to fit within the five sizes. One Marine refused to be measured.

The unit tariff was compared to a tariff calculated from the USMC anthropometric database (Table 2). Then to determine how similar the study group was to the database population, means of age and chest circumference were compared. Both were significantly different ($p < .05$). The study group was 2.5 years younger and had a chest circumference 12.6mm (1/2 inch) larger than the database (Table 3 & Appendix A).

Table 2. Tariff Comparison

| Predicted Size | Field Study Frequency | Field Study Percent | Field Study Tariff | Database Tariff | Difference |
|----------------|--------------------------|------------------------|-----------------------|--------------------|------------|
| XSmall | 4 | .4 | 4 | 3 | 1 |
| Small | 154 | 15.0 | 150 | 199 | -49 |
| Medium | 560 | 54.5 | 545 | 560 | -15 |
| Large | 267 | 26.0 | 260 | 215 | 45 |
| XLarge | 41 | 4.0 | 41 | 23 | 18 |
| 6 | 1 | .1 | | | |
| Total | 1027 | 99.9 | 1000 | 1000 | |
| Missing | 1 | 100 | | | |

Table 3. Summary Statistics for Age & Chest Circumference

| Variable | Source | N | Min | Max | Mean | Std. Dev. |
|-------------|--------------------|------|-----|------|--------|-----------|
| Age | Interceptor | 1027 | 18 | 49 | 22.9 | 4.59 |
| | 1995 USMC database | 4447 | 17 | 55 | 25.4 | 6.49 |
| Chest Circ. | Interceptor | 1027 | 816 | 1248 | 1008.8 | 70.42 |
| | 1995 USMC database | 4447 | 775 | 1330 | 996.2 | 67 |

Fit Evaluation

The goal for the number of Marines evaluated in each size, based on size predicted from chest circumference, was exceeded by 43% (Table 4). The range of values for all dimensions measured was from the 5th to the 95th percentile values (Donelson & Gordon, 1996) or greater (Table 5). To illustrate the range of body measurements in this sample, a plot of chest circumference and stature was compared to the USMC anthropometric database (Figure 3). Appendix B contains additional comparisons of the fit evaluation sample with the database.

Table 4. Marines Fit Tested by Size.

| Predicted Size | Sample Goal | Total Evaluated |
|----------------|---------------|-----------------|
| X Small | all available | 3 |
| Small | 50 | 69 |
| Medium | 50 | 74 |
| Large | 50 | 72 |
| X Large | all available | 32 |
| Other | | 1 |
| Total | | 251 |

Table 5. Anthropometric Range of Fit Test Participants.

| Variable | N | Minimum | Database Percentile | Maximum | Database Percentile | Mean |
|-------------------------|-----|---------|------------------------|---------|------------------------|--------|
| Neck Circumference | 250 | 378 | 5 th | 527 | 99 th | 446.8 |
| Chest Circumference | 251 | 816 | 1 st | 1248 | 99 th | 1013.2 |
| Waist Circumference, O. | 251 | 689 | 1 st | 1127 | 99 th | 859.7 |
| Waist Front Length, O. | 251 | 317 | 1 st | 456 | 95 th | 386.7 |
| Stature | 251 | 1566 | 1 st | 1959 | 99 th | 1749.7 |
| Weight | 249 | 497 | 1 st | 1212 | 99 th | 806.3 |

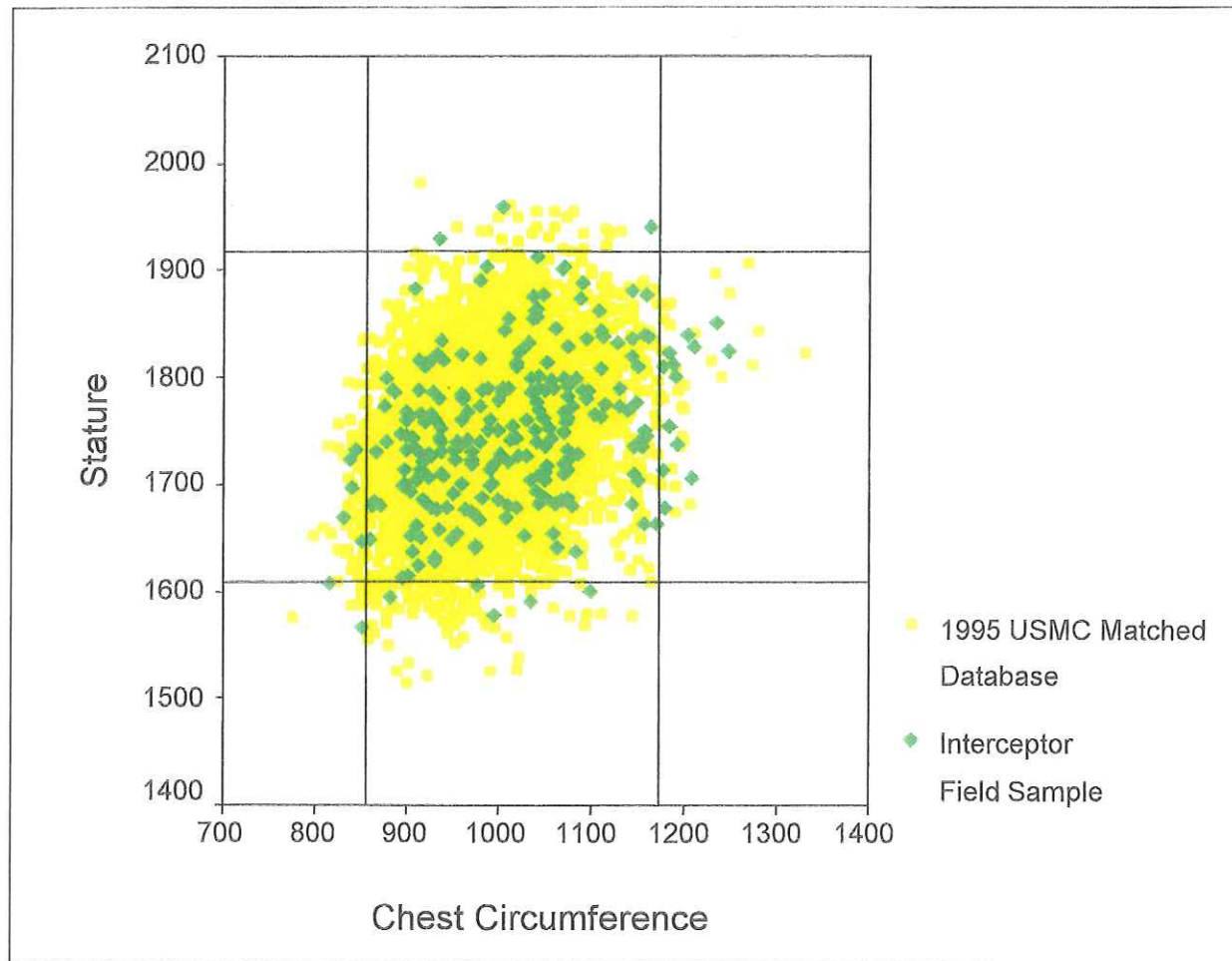


Figure 3. Anthropometric comparison of fit test group with USMC database. (Grid lines represent 1st and 99th percentile values for each variable. Values in mm.)

Overall, the predicted size was rated acceptable by 84.7% of the participants. The predicted size was also the best fitting size for 70.4% of the Marines evaluated, but there was considerable variation across sizes (Table 6). The best fitting size was smaller than the predicted size for 27.2 % and larger than the predicted size for 2.4% (Figure 4). Complete results for all sizes combined are presented in Figure 5.

Table 6. Predicted vs. Best Fitting Size.

| | | Best Fitting Size | | | | | Table Total |
|----------------|---------|-------------------|-------------|-------------|-------------|-------------|---------------|
| | | XSmall | Small | Medium | Large | XLarge | |
| Predicted Size | XSmall | 3 100.0% | | | | | 3 |
| | Small | 4 5.8% | 65 94.2% | | | | 69 |
| | Medium | | 16 21.6% | 53 71.6% | 5 6.8% | | 74 |
| | Large | | | 28 38.9% | 43 59.7% | 1 1.4% | 72 |
| | XLarge | | | | 19 61.3% | 12 38.7% | 31 |
| | Other | | | | | 1 100.0% | 1 |
| | Missing | | | | | | 1 |
| | | | | | | | 251 100.0% |

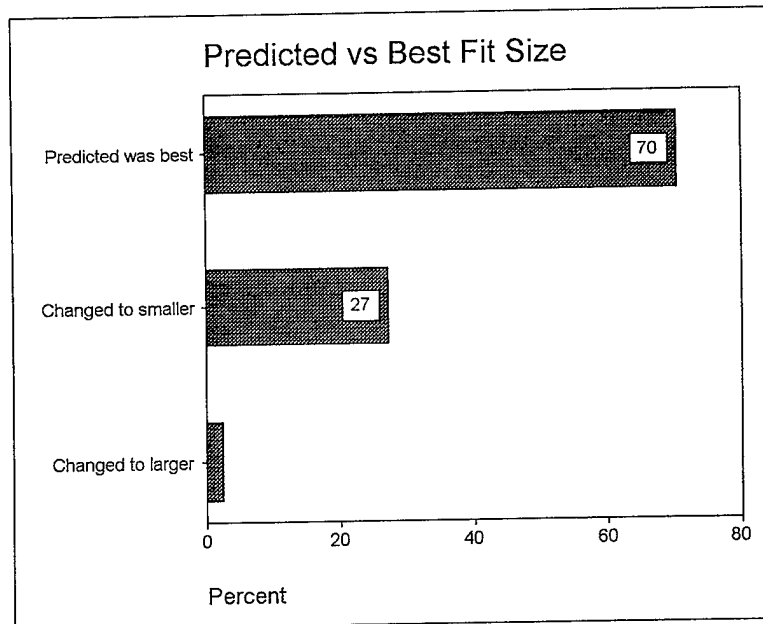


Figure 4. Change from predicted size to get best fit.

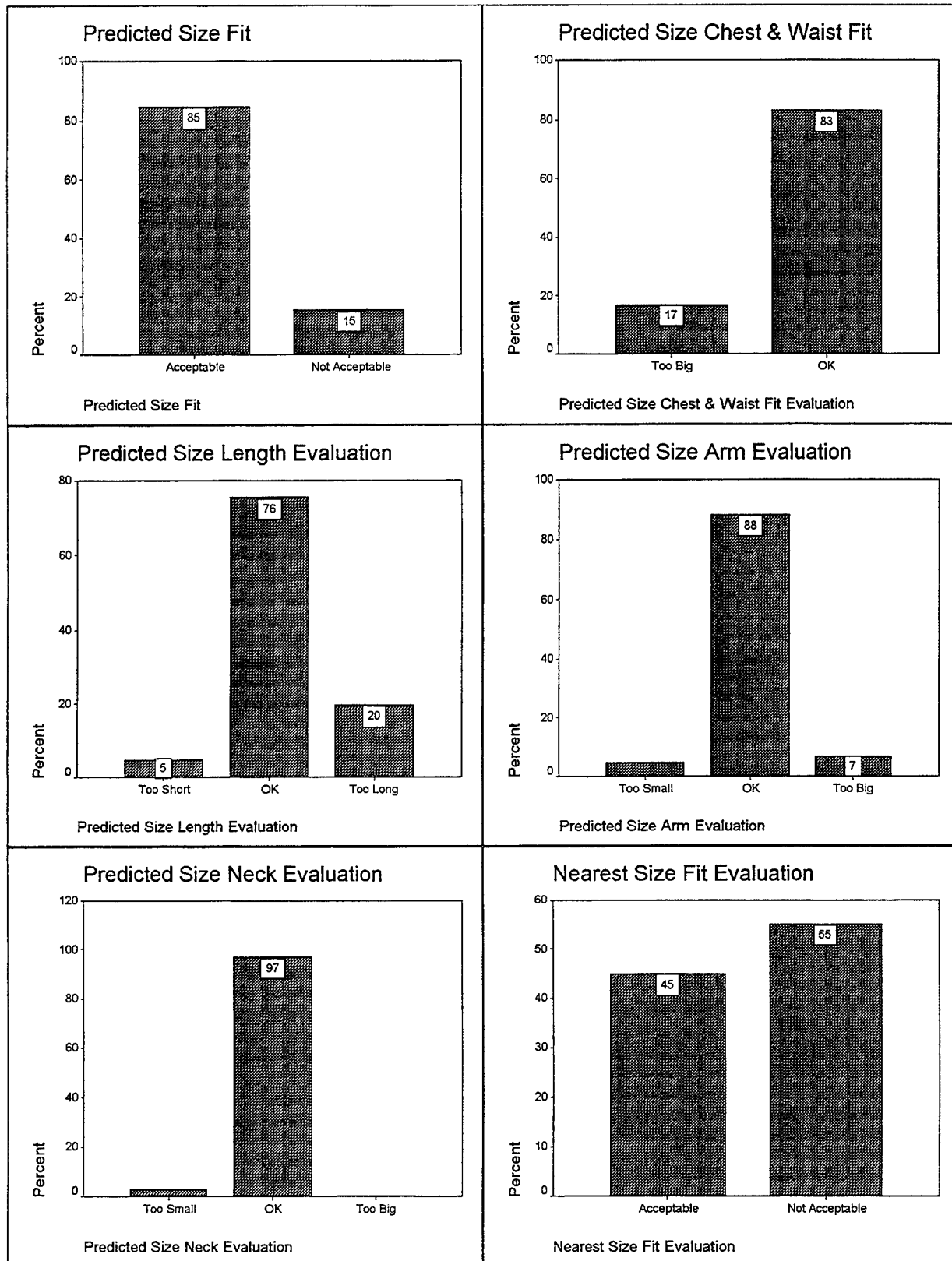


Figure 5. Overall evaluations

Results by size for Small, Medium, Large, and XLarge are presented in Appendix C. The results for XSmall were not summarized because there were only three Marines predicted into that size and it was the best fit for all three. A list of fit evaluation comments directly related to the fit and sizing of the Interceptor is presented in Table 7.

Table 7. Fit Evaluation Comments.

Marine preferred looser fit across chest

XS slightly short on top of shoulder

Med slightly narrow over shoulder

Med was cinched all the way at sides and was too wide across chest, but small did not provide good overlap at sides

Medium material bunched at arms

Large big at waist but chest OK

Large groin protector slightly short

Large slightly short

Large tightened all the way and still big

Large too big at waist and too long

Large waist slightly big and groin protector a little short

Marine preferred loose fit of large

XL big at waist

XL binding at arms

XL slightly long. Marine preferred smaller vest for better movement through vehicle hatch.

Chest circ is larger than range for XL

The Follow Up Survey

The survey was an opportunity for Marines to provide feedback on the fit of the Interceptor after actually using it for a period of time. Only surveys from Marines who were measured for predicted size in the first part of the study were included, and 98.1 % were using the same vest originally issued. A total of 30 Small, 107 Medium, 23 Large, and 1 X Large was evaluated. The Interceptor provided an overall satisfactory fit to 77% of those surveyed and rated substantially better than the previously used body armor (PASGT) except in ability to move while wearing it. In that case, the two were rated nearly the same with 51% preferring the Interceptor and 49% the previous armor. Complete results are summarized in Tables 8 and 9. The most frequent comments from all sections of the survey are summarized in Table 10.

Table 8. Survey Results Related to Fit of the Interceptor (N = 161)

| | YES | NO |
|--|------------|------------|
| Were you able to adjust vest to fit? | 89% | 11% |
| Were you satisfied with the overall fit? | 77% | 23% |
| Would a different size fit better? | 11% | 89% |
| Was there interference with clothing or equipment? | 17% | 83% |

Table 9. Body Armor Comparison (N = 161)

| | Interceptor | PASGT |
|--------------------------------------|--------------------|--------------|
| Better sizing & fit | 83% | 17% |
| Better body area coverage | 94% | 6% |
| Better level of protection | 97% | 3% |
| Better ability to move while wearing | 51% | 49% |
| Better compatibility with clothing | 78% | 22% |
| Better compatibility with equipment | 83% | 17% |
| Better ability to perform mission | 78% | 22% |
| Better overall | 86% | 14% |

Table 10. Most Frequent Comments (N = 161)

| | |
|----------------------|-----|
| Poor ventilation | 19% |
| Needs pockets | 9% |
| Too hot | 8% |
| Too long | 6% |
| Hard to breathe | 6% |
| Arms restricted | 5% |
| Collar uncomfortable | 5% |
| Hard to fit LBV | 5% |
| Hard to move | 4% |

Discussion and Recommendations

There are a few points about this study that must be emphasized before interpreting the results and applying them to change the Interceptor design and tariff. The population sample of the study group does not seem to be truly representative of the U.S. Marine Corps population as a whole. The main difference is age, and there are some smaller differences in the racial/ethnic composition. Each can affect anthropometric variation. However, the two units that participated are actual ground combat units, the ones likely to receive the Interceptor first and to use it most often in their duties. The sample size of 1027 is large enough to assume that the observed chest circumference distribution should be close to the population-wide distribution in these types of units. Also, the range of anthropometric variation found in the fit test group is very similar to that of the USMC database (Appendix B). It would be reasonable to base any change in the anthropometric tariff for males on these units.

Size determination for issuing the Interceptor in the study was based on the careful measurement of chest circumference by a trained physical anthropologist. Obviously this will not be the case for other Marines being issued the Interceptor in the future. However, a measurement of chest circumference should be done to determine the appropriate size for issue for all Marines. The design and tariff of the Interceptor are based on specific measurements. If it is issued using some other criteria, the tariff will not be accurate.

The predicted size was the best fit for 70% of those evaluated and was rated as acceptable by 85%. These are very high ratings considering that the vest has only five sizes and is only sized on one dimension, chest circumference. However, the ratings varied greatly for different sizes, and there were some consistent patterns in the evaluations of the sizes with lower ratings. The two main reasons for someone's predicted size to be rated unacceptable were: 1) the chest/waist circumference was too big, and 2) the vest was too long, especially in the front.

Based on this information and the frequency distribution of the anthropometric dimensions evaluated in the fit test, the following recommendations are made for changes to each size:

- *XSmall*
 - No recommendations can be made without a larger sample, including females.
- *Small*
 - No changes.
- *Medium*
 - Reduce waist circumference by 1 inch. This could increase rating of chest/waist as OK from 86% to 96%.
 - Reduce the front length by ½ inch. This could increase rating of length as OK from 82% to 90%.
- *Large*
 - Reduce chest circumference by ½ inch and waist circumference by 1 inch. This could increase rating of chest/waist as OK from 76% to 92%.
 - Reduce front and back length by ½ inch. This could increase rating of length as OK from 67% to 81 %.
- *XLarge*
 - Reduce chest circumference by ½ inch and waist circumference by 1 inch. This could increase rating of chest/waist as OK from 63% to 90%.
 - Reduce front and back length by ¾. This could increase rating of length as OK from 63% to 82%.

As an example of how the predicted ratings were determined, consider the change for the size Medium waist circumference. By comparing the values of waist circumference for those who rated chest/waist OK and those who rated it Too Big, this change of 1 inch should accommodate 10 Marines who rated the chest/waist as Too Big. However, it will likely mean that 3 Marines previously rated OK but with large waists will no longer be fit. There is a net gain of 7 Marines accommodated, or 10% of those whose predicted size is Medium.

In all sizes there was also an excess of material in the arm scye area that seemed to interfere with arm movement. This material was part of the external carrier, not the ballistic protective inserts. Trimming this material closer to the inserts should alleviate the interference.

Ideally, increasing the acceptability of these individual dimensions will result in an overall increase in acceptability. However, the effect of these changes on those individuals who already find the fit acceptable can not be known. Further increases in acceptability can only be achieved by creating additional sizes for the Interceptor based on length in addition to chest circumference (for example, Large-Short and Large-Long rather than just Large). Improving the sizing and fit of the Interceptor will make calculating a tariff from anthropometric data more accurate.

Although the study sample may be somewhat different from the USMC database sample, the Interceptor tariffs for both were similar. Had the male only database tariff been used to outfit

the field sample, 94% of the Marines would have been accommodated, and a total of 63 additional vests would have been needed to accommodate 100% of the Marines, based on the size predicted by chest circumference. This indicates that the database tariff would be reasonable to use for initial production of the Interceptor. However, since there seems to be a pattern in how the tariffs differ, a slight change could provide even better results (Table 11 and Figure 6). The revised tariff is based on the average of the database tariff and the field tariff.

Table 11. Recommended Tariff for USMC Interceptor

| | Male | Female | All USMC* |
|--------|------|--------|-----------|
| XSmall | 4 | 110 | 10 |
| Small | 174 | 709 | 204 |
| Medium | 553 | 164 | 531 |
| Large | 238 | 16 | 226 |
| XLarge | 31 | 1 | 29 |
| | 1000 | 1000 | 1000 |

Calculated from the 1995 Matched Anthropometric Database of U.S. Marine Corps Personnel & the Interceptor fit test and field tariff study, April - July 1999.

*Based on active duty strength for September 1998:
94.35% Male, 5.65% Female

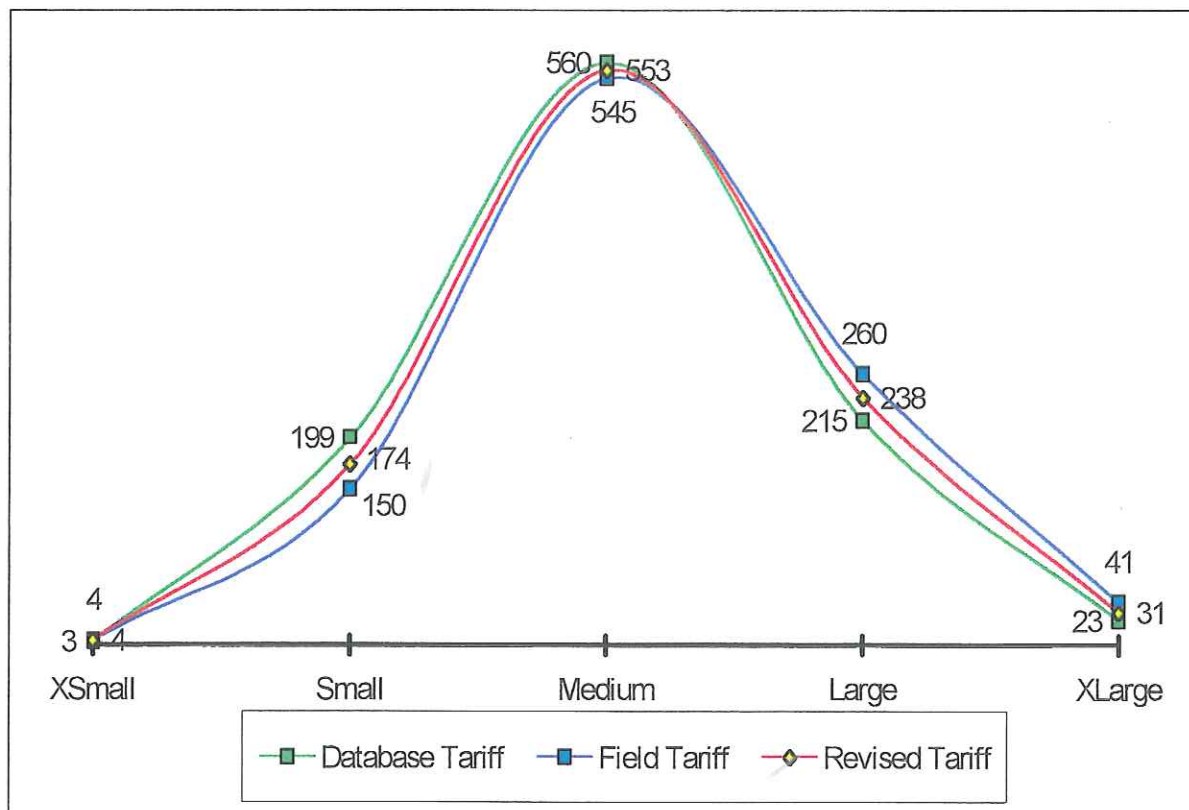


Figure 6. Tariff Comparisons.

This document reports research undertaken at the U.S. Army Soldier and Biological Chemical Command, Soldier Systems Center, and has been assigned No. NATICK/TR-001014 in a series of reports approved for publication.

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APPENDICES

APPENDIX A

Results of Statistical Tests for Equality of Variances and Means for Age and Chest Circumference

APPENDIX A

Table A-1. Test for Equality of Variance for Age. (x = Interceptor sample, y = 1995 USMC database)

| | | | | | | |
|--|------|------|-----------|-----------|----------------------|---|
| sdtesti 1027 . 4.59 4447 . 6.49 | | | | | | |
| Variance ratio test | | | | | | |
| | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. Interval] | |
| x | 1027 | . | .1432278 | 4.59 | . | . |
| y | 4447 | . | .097322 | 6.49 | . | . |
| combined | 5474 | . | . | . | . | . |
| Ho: sd(x) = sd(y) | | | | | | |
| F(1026,4446) observed = F_obs = 0.500 | | | | | | |
| F(1026,4446) lower tail = F_L = F_obs = 0.500 | | | | | | |
| F(1026,4446) upper tail = F_U = 1/F_obs = 1.999 | | | | | | |
| Ha: sd(x) < sd(y) Ha: sd(x) ~= sd(y) Ha: sd(x) > sd(y) | | | | | | |
| P < F_obs = 0.0000 P < F_L + P > F_U = 0.0000 P > F_obs = 1.0000 | | | | | | |

Table A-2. Test for Equality of Variance for Chest Circumference. (x = Interceptor sample, y = 1995 USMC database)

| | | | | | | |
|--|------|------|-----------|-----------|----------------------|---|
| . sdtesti 1027 . 70.42 4447 . 67.00 | | | | | | |
| Variance ratio test | | | | | | |
| | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. Interval] | |
| x | 1027 | . | 2.197408 | 70.42 | . | . |
| y | 4447 | . | 1.004711 | 67 | . | . |
| combined | 5474 | . | . | . | . | . |
| Ho: sd(x) = sd(y) | | | | | | |
| F(1026,4446) observed = F_obs = 1.105 | | | | | | |
| F(1026,4446) lower tail = F_L = 1/F_obs = 0.905 | | | | | | |
| F(1026,4446) upper tail = F_U = F_obs = 1.105 | | | | | | |
| Ha: sd(x) < sd(y) Ha: sd(x) ~= sd(y) Ha: sd(x) > sd(y) | | | | | | |
| P < F_obs = 0.9805 P < F_L + P > F_U = 0.0422 P > F_obs = 0.0195 | | | | | | |

Table A-3. Test for Equality of Means for Age. (x = Interceptor sample, y = 1995 USMC database)

```
. ttesti 1027 22.91 4.59 4447 25.41 6.49, unequal
```

Two-sample t test with unequal variances

| | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. Interval] | |
|----------|------|----------|-----------|-----------|----------------------|-----------|
| x | 1027 | 22.91 | .1432278 | 4.59 | 22.62895 | 23.19105 |
| y | 4447 | 25.41 | .097322 | 6.49 | 25.2192 | 25.6008 |
| combined | 5474 | 24.94096 | .0845356 | 6.25449 | 24.77524 | 25.10669 |
| diff | | -2.5 | .1731641 | | -2.839592 | -2.160408 |

Satterthwaite's degrees of freedom: 2089.36

Ho: mean(x) - mean(y) = diff = 0

| | | |
|----------------|------------------|----------------|
| Ha: diff < 0 | Ha: diff ~= 0 | Ha: diff > 0 |
| t = -14.4372 | t = -14.4372 | t = -14.4372 |
| P < t = 0.0000 | P > t = 0.0000 | P > t = 1.0000 |

Table A-4. Test for Equality of Means for Chest Circumference. (x = Interceptor sample, y = 1995 USMC database)

```
. ttesti 1027 1008.79 70.42 4447 996.19 67, unequal
```

Two-sample t test with unequal variances

| | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. Interval] | |
|----------|------|----------|-----------|-----------|----------------------|----------|
| x | 1027 | 1008.79 | 2.197408 | 70.42 | 1004.478 | 1013.102 |
| y | 4447 | 996.19 | 1.004711 | 67 | 994.2203 | 998.1597 |
| combined | 5474 | 998.5539 | .9167469 | 67.82688 | 996.7568 | 1000.351 |
| diff | | 12.6 | 2.416205 | | 7.860461 | 17.33954 |

Satterthwaite's degrees of freedom: 1484.85

Ho: mean(x) - mean(y) = diff = 0

| | | |
|----------------|------------------|----------------|
| Ha: diff < 0 | Ha: diff ~= 0 | Ha: diff > 0 |
| t = 5.2148 | t = 5.2148 | t = 5.2148 |
| P < t = 1.0000 | P > t = 0.0000 | P > t = 0.0000 |

APPENDIX B

Anthropometric Comparison of the Fit Evaluation Sample with the 1995 Matched Anthropometric Database of USMC Personnel

APPENDIX B

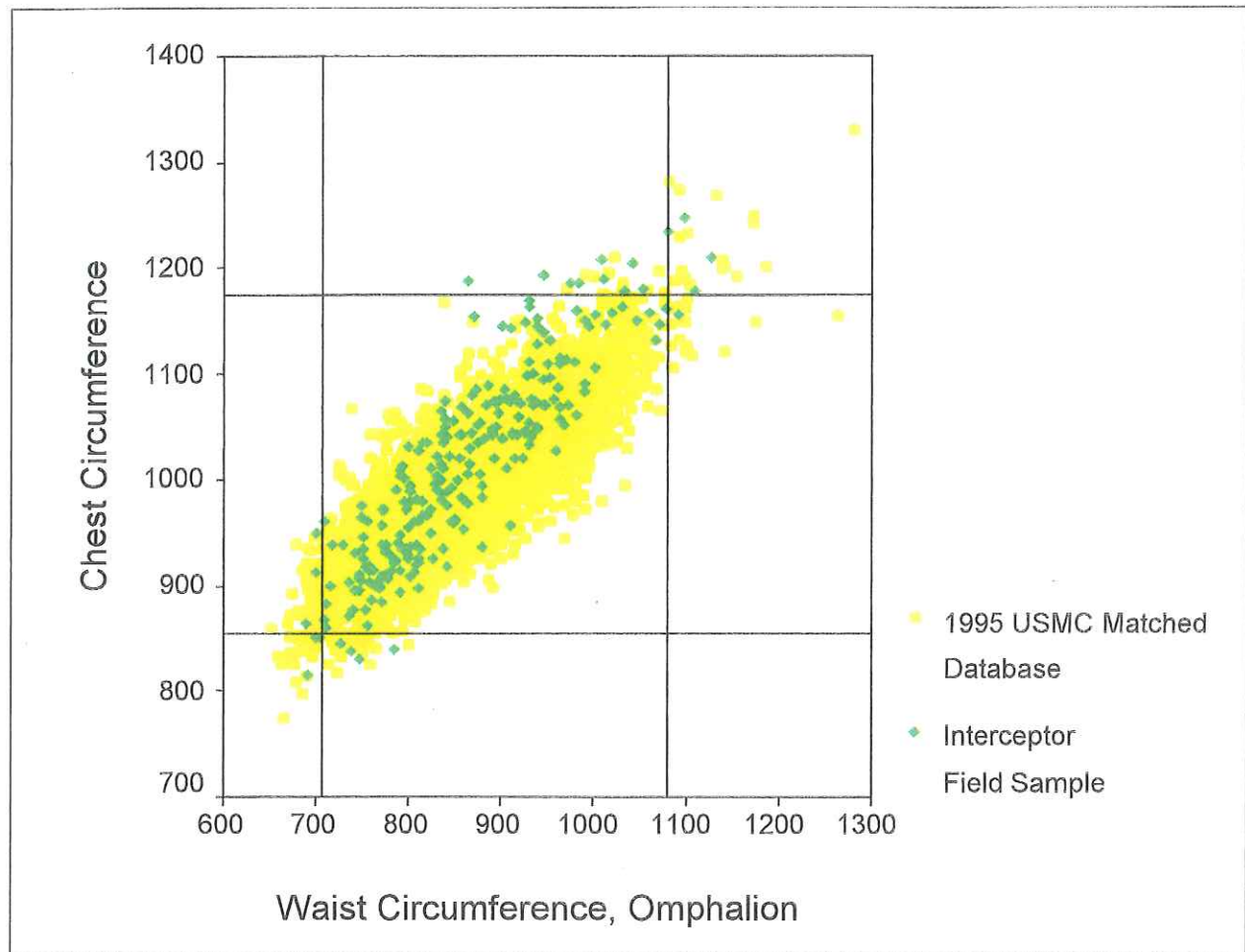


Figure B-1. Anthropometric comparison of fit test group with USMC database. (Grid lines represent 1st and 99th percentile values for each variable. Values in mm.)

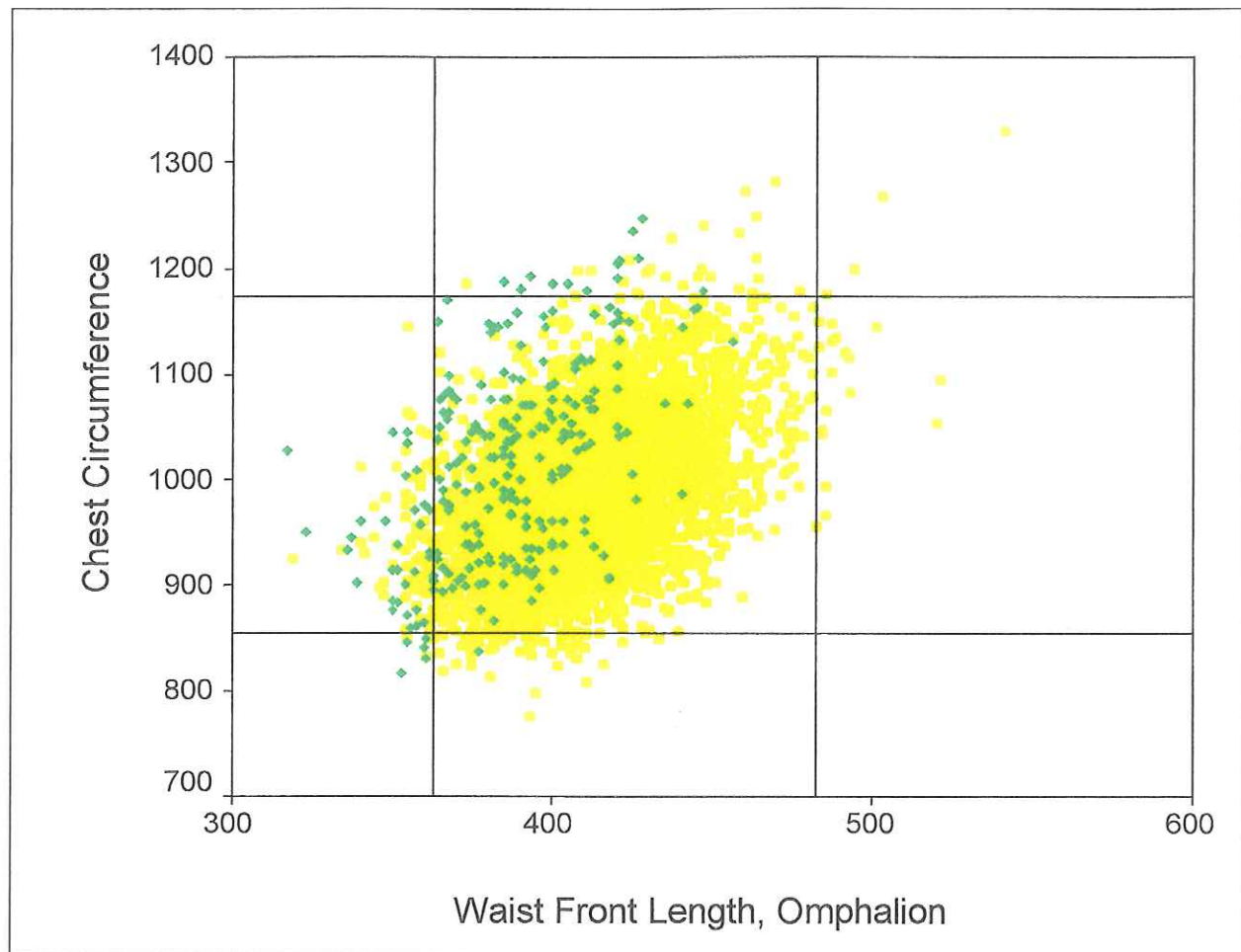


Figure B-2. Anthropometric comparison of fit test group with USMC database. (Grid lines represent 1st and 99th percentile values for each variable. Values in mm.)

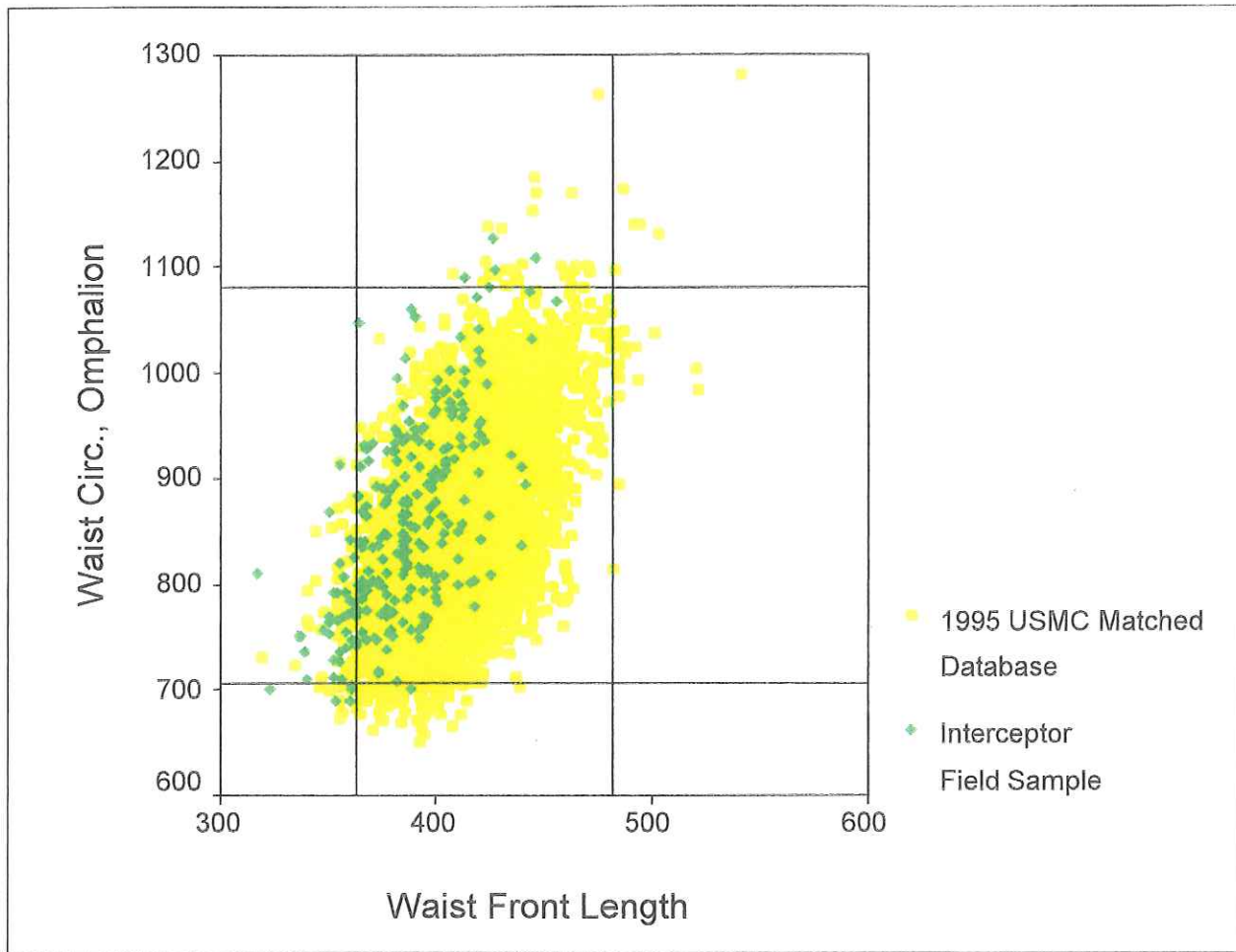


Figure B-3. Anthropometric comparison of fit test group with USMC database. (Grid lines represent 1st and 99th percentile values for each variable. Values in mm.)

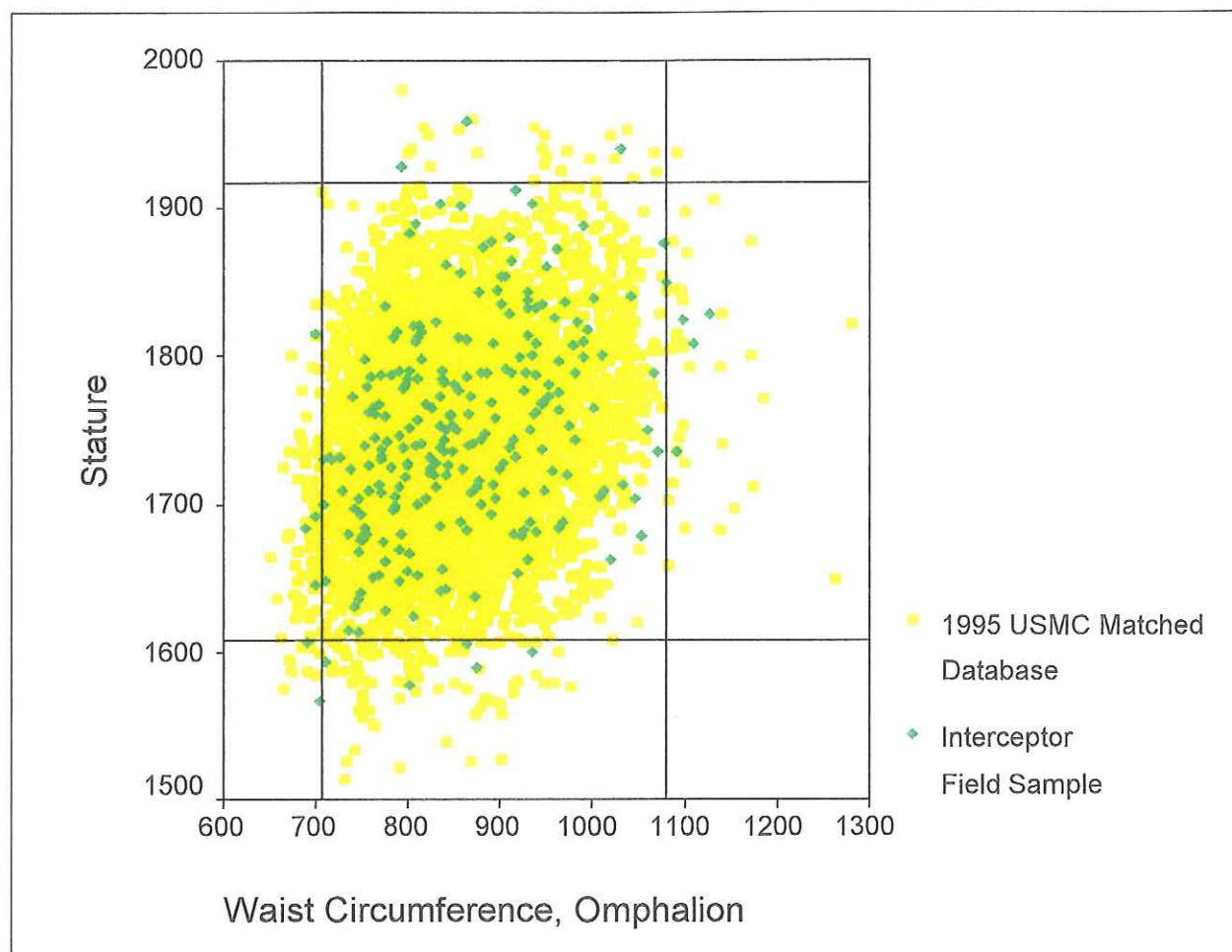


Figure B-4. Anthropometric comparison of fit test group with USMC database. (Grid lines represent 1st and 99th percentile values for each variable. Values in mm.)

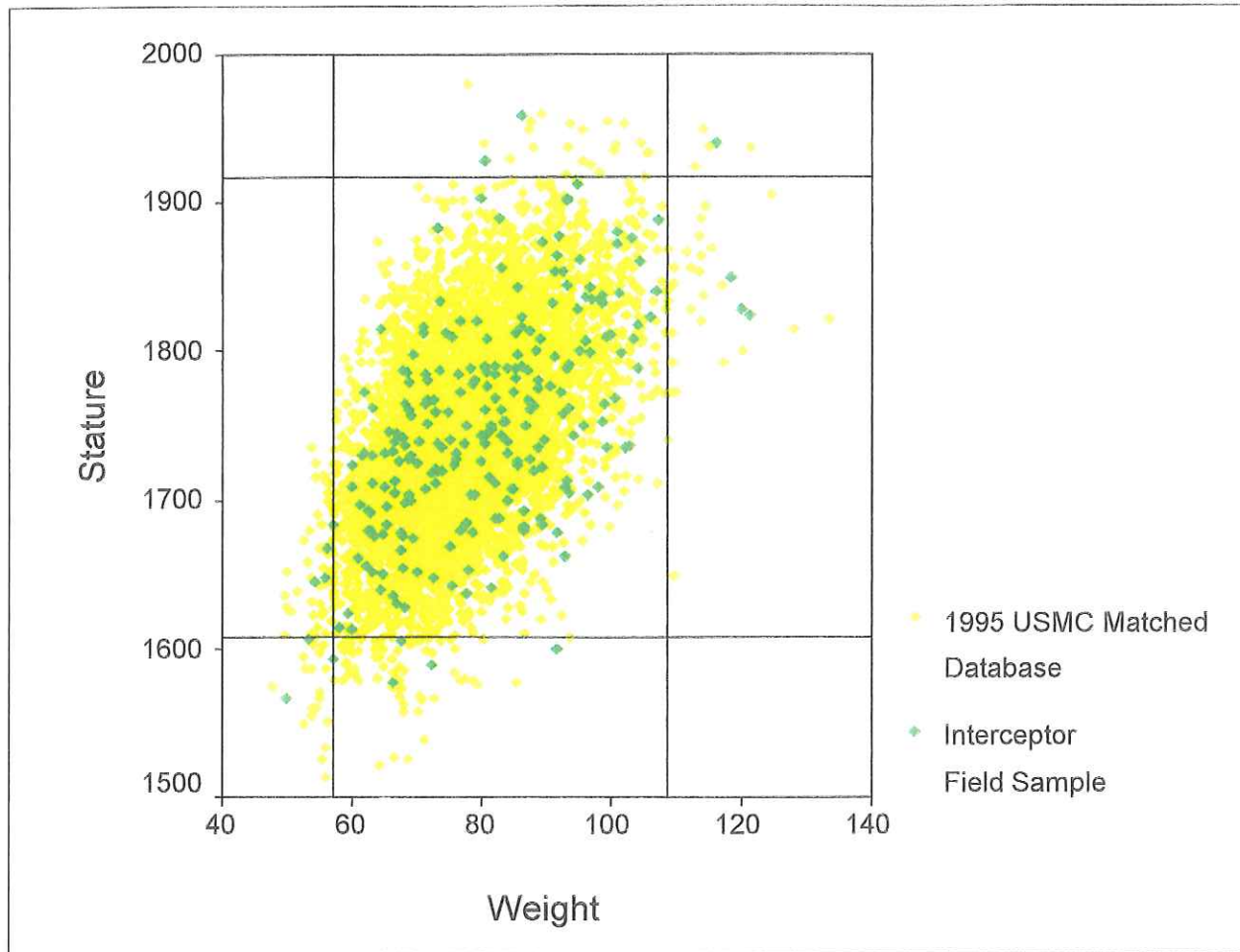


Figure B-5. Anthropometric comparison of fit test group with USMC database. (Grid lines represent 1st and 99th percentile values for each variable. Stature in mm, Weight in kg.)

APPENDIX C

Fit Evaluation Results by Size

APPENDIX C

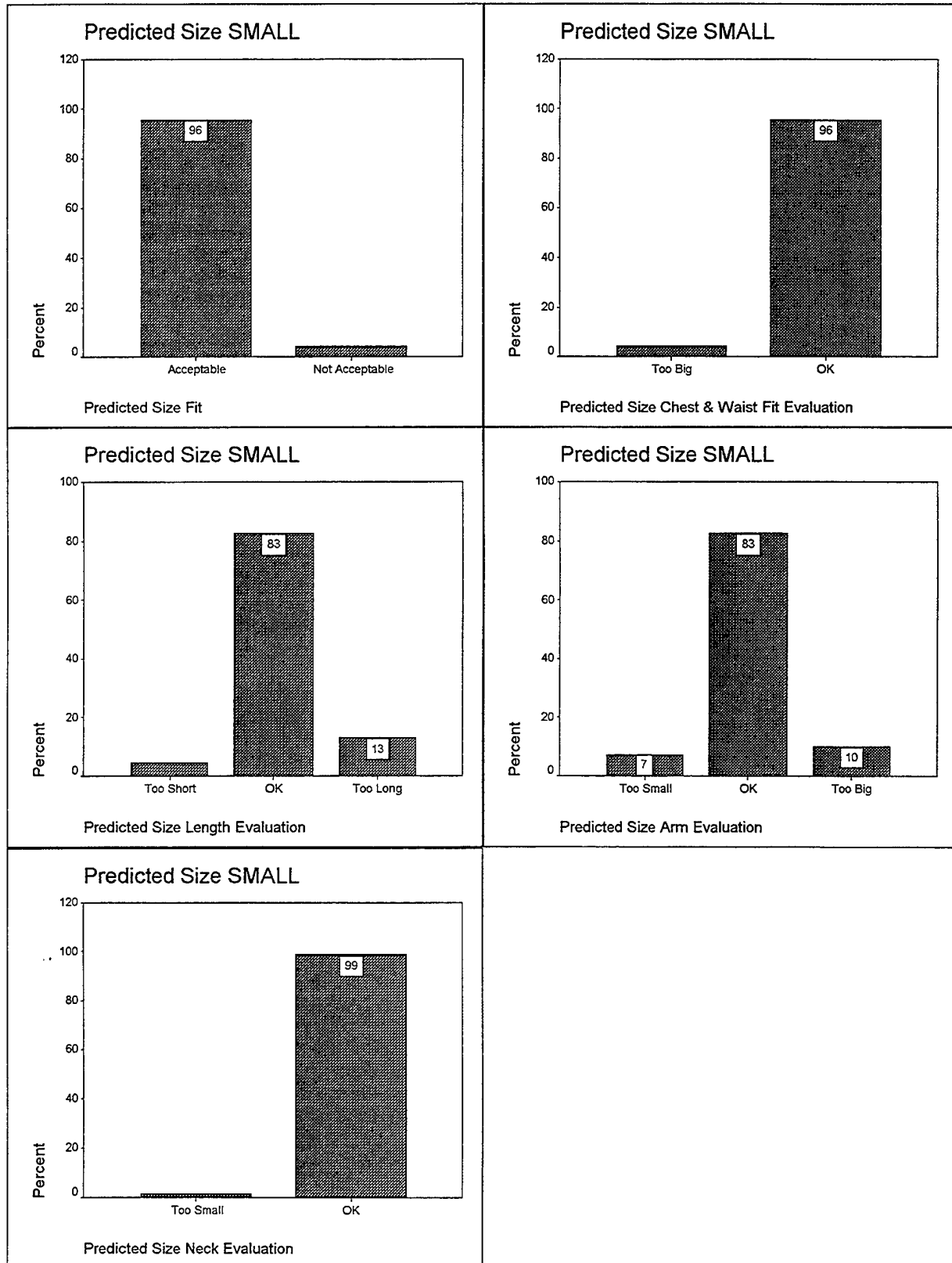


Figure C-1. Small size evaluations

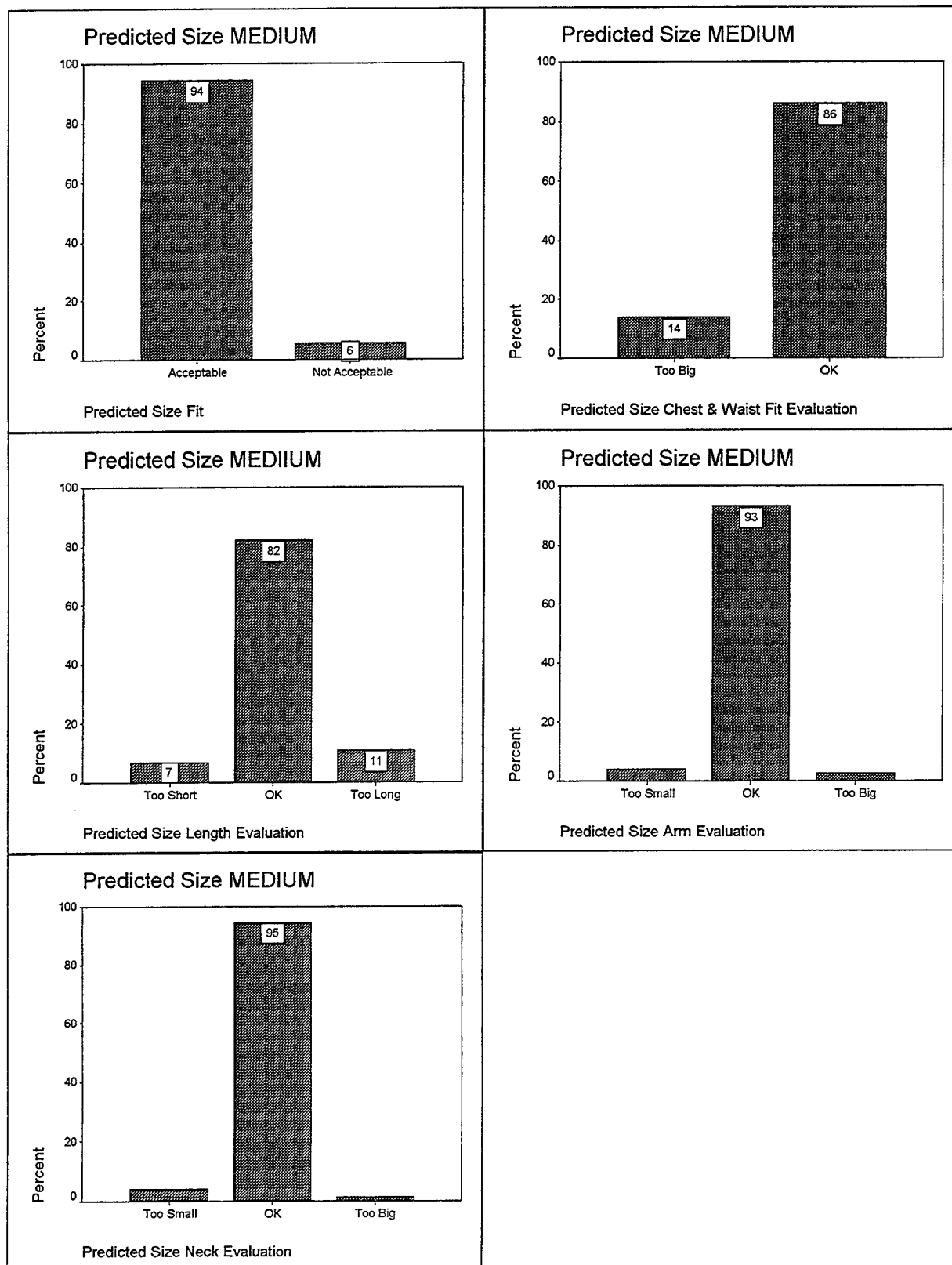


Figure C-2. Medium size evaluations.

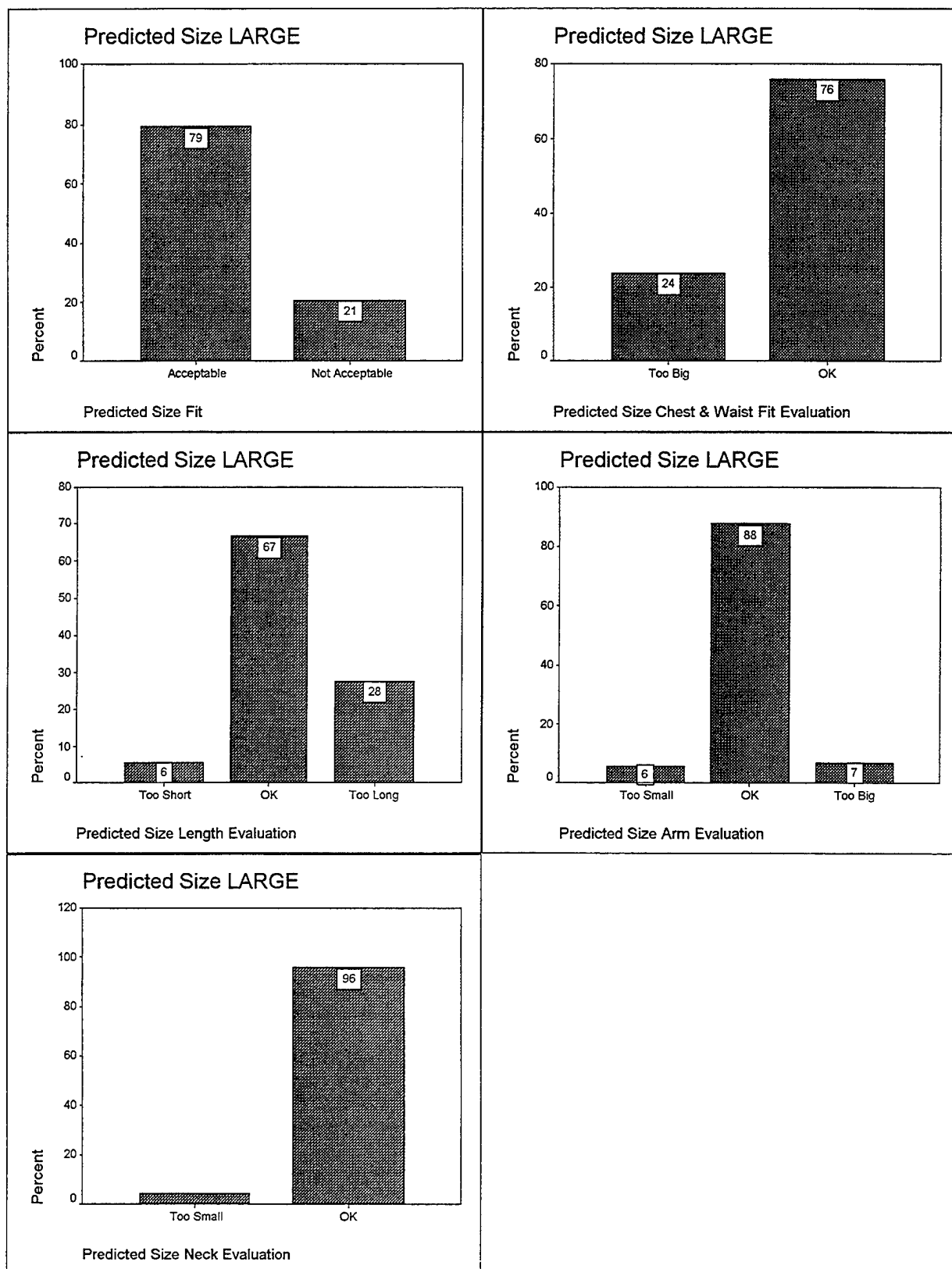


Figure C-3. Large size evaluations

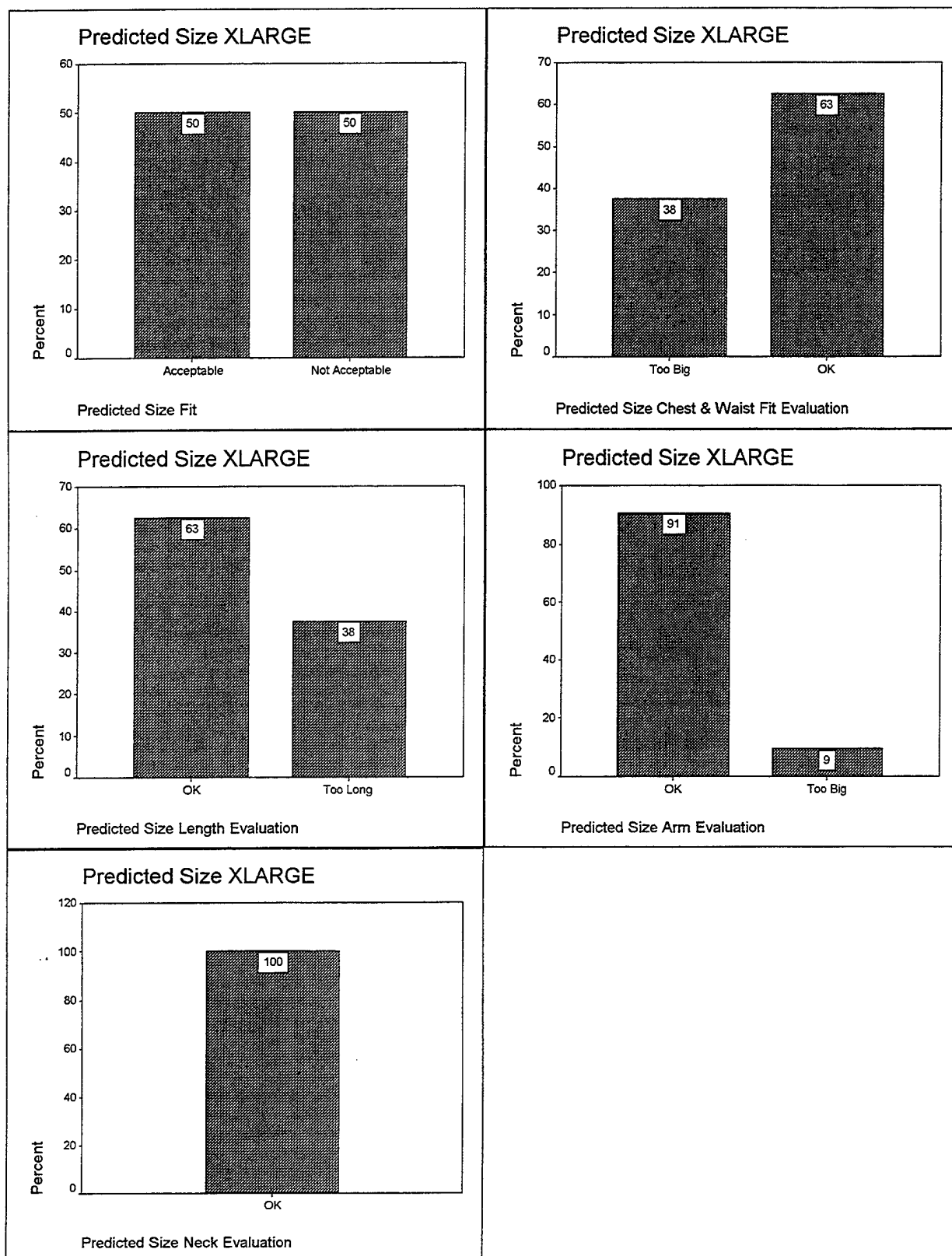


Figure C-4. XLarge size evaluations